DESIGN OF AN ENHANCED DRAINAGE SYSTEM USING HIGH-DENSITY POLYETHYLENE (HDPE) PIPE AND ASSESSMENT OF ITS PERFORMANCE IN SANTA MARIA PUBLIC MARKET, POBLACION, SANTA MARIA, BULACAN

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Degree Bachelor of Science in Civil Engineering

Major in Construction Engineering and Management

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RECOMMENDATION

This is to certify that this research entitled "DESIGN OF AN ENHANCED DRAINAGE SYSTEM USING HIGH-DENSITY POLYETHYLENE (HDPE) PIPE AND ASSESSMENT OF ITS PERFORMANCE IN SANTA MARIA PUBLIC MARKET, POBLACION, SANTA MARIA, BULACAN", prepared and submitted by Jessica Mae L. Ignacio, Kristine May B. Macalalag, and Mark Daniel I. Sinon has been examined and PASSED the PRE-ORAL DEFENSE.

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We hereby certify that this research paper titled “Design of an Enhanced Drainage System using High-Density Polyethylene (HDPE) Pipe and Assessment of its Performance in Santa Maria Public Market, Poblacion, Santa Maria, Bulacan” is the researchers own work. It contains no material previously written or published by another individual, group, or organization. In addition, it states that no any material has been accepted for a recognition from other degree, university, institution, colleges or higher learning, except where appropriately acknowledged.

Furthermore, we declare that the intellectual content of this thesis is the result of our hard work, however, we acknowledge receiving guidance from others on organization, presentation, language, and style.

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CHAPTER 1

The Problem and Its Background

This chapter presents an overview of the study including the introduction, background of the study, theoretical framework, conceptual framework, statement of the problem, hypothesis, significance of the study, scope and limitations, and definition of terms.

Introduction

Drainage systems are important parts of infrastructure as they ensure environmental cleanliness, prevent flooding, and manage health risks. Public markets, being centers of trade, serve as key areas where the effectiveness of drainage systems directly affects not only vendors and customers but also the community. These markets encounter many problems such as dirty water, foul odors, flooding, insect diseases, and contamination of surrounding waterways when drainage systems are poorly planned, not properly maintained, or unable to meet demand. In addition, these conditions also pose serious threats to public health, particularly through the spread of illness caused by the water.

Many public markets in the Philippines still rely on old and inefficient infrastructure, even though effective drainage systems are very important. The

problem is often made worse by limited government funding, lack of awareness, and weak enforcement of sanitation laws. Because of this, the condition of drainage systems in public markets has become a serious concern that requires proper solutions, as it affects not only environmental management but also public health.

Background of the Study

The Santa Maria Public Market in Poblacion, Santa Maria, Bulacan, serves as an economic hub for small businesses and provides access to affordable goods to the consumers. They are essential venues where local vendors can sell their goods to the community. However, the current drainage system of the existing public market is in poor condition. The drainage is often filled with dirt, garbage and other solid waste which block the flow of water. Because of this, the market easily experiences flooding even during light rainfall. The water cannot move properly, therefore, it stays in the area and becomes stagnant. The stagnant water, along with the accumulated waste, results in strong foul odor making the public market an unhealthy place for the vendors who work and sell every day, to the customers who come to buy goods, residents and even the people who pass by. The poor and failing drainage systems require urgent and effective measures to control flooding to ensure the safety of the community.

Addressing this serious infrastructure problem requires the design and implementation of an enhanced drainage solution that prioritizes long-term efficiency, performance, and sustainability, with the ability to resist blockages and manage stormwater and wastewater effectively. This research proposes using High-Density

Polyethylene (HDPE) pipe in the design of the new drainage system for the Santa Maria Public Market. According to Pluimer and Padden (2025), the HDPE pipes manufactured with recycled materials are performing comparably to those made from new and unused materials. Besides their good performance, the use of HDPE pipe offers many benefits which are relevant to a public infrastructure project in need of both durability and sustainability. The use of recycled materials in HDPE pipes shows that it is a more sustainable choice, offering significant environmental benefits and a lower carbon footprint compared to pipes manufactured only with new materials. Furthermore, a life-cycle cost analysis (LCCA) shows that the use of HDPE pipes manufactured with recycled materials can result in significant cost saving compared to alternatives like Reinforced Concrete Pipe (RCP). By designing an enhanced system using HDPE, this study aims to assess its performance in mitigating the current flooding and unsanitary conditions, providing a strong, cost-effective, and sustainable solution for public market infrastructure in Santa Maria, Bulacan.

Theoretical Framework

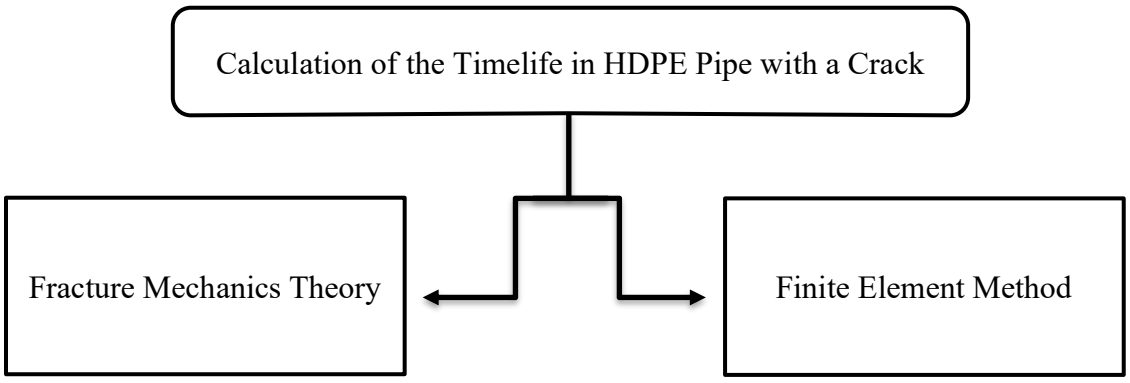

Figure 1. Theoretical Framework Model

The researchers link these two theories due to their significant relevance to the ongoing study. The Fracture Mechanic Theory describes how cracks begin and develop in materials exposed to various stress conditions. It emphasizes the significance of the stress intensity factor (KI), which determined when a crack becomes critical and could result in to structural loss. This theory function as the scientific basis for estimating the strength, durability, and service life of HDPE pipes used in drainage systems. The second theory acts as a computational framework that models and simulates stress distribution and crack growth in HDPE pipes. By using the finite element method (FEM), the researchers can properly evaluate how pressure, temperature, and defect size affect the pipe's performance**.** The two theories were linked together because both focus on comprehension with the mechanical behavior and expected potential breakdown of HDPE pipes, assuring that drainage systems remain effective, safe, and stable over time.

Conceptual Framework

INPUT	PROCESS	OUTPUT
1. Participants profile: 1.1. Age 1.2. Sex 1.3. Frequency of going to public market 1.4. Length of residency 2. Assessment that affect the public market due to flooding in terms of: 2.1. Condition of drainage 2.2. Topography and slope of area 2.3. Lack of proper monitoring 2.4. Solid waste management practices 2.5. Capacity of drainage 3. The effectivity on design implementation of the drainage system in terms of: 3.1. Layout and functionality of drainage system 3.2. Cost-effective materials used in construction 3.3. Operation and maintenance 4. The improvement on the design of public market drainage system that benefited	1. Data gathering through a survey questionnaire. 2. Analysis and identification of issues affecting the drainage and flooding. 3. Evaluation of the implemented drainage system and performance through site inspection, layout, cost-effective and operations. 4. Assessment and analysis of the planned drainage system improvements determined by measures of data analysis.	1. Comprehensive demographic profile of the participants and community awareness. 2. Proposed strategies to reduce flooding in the public market and cognitive understanding for the growing flood issue. 3. Continuous flow of economic activity, improved sanitation and public safety. Extended lifespan of the drainage infrastructure. 4. Sustainability of the improved drainage system in environment, safer, cleaner and more stable community in the public market.

the users be measured in terms of: 4.1. Environmental impact 4.2. Safety and resilience		

Figure 2. The Conceptual Model of the Study

Statement of the Problem

The general aim of this study is to determine the "Design of an Enhanced Drainage System using High-Density Polyethylene (HDPE) Pipe and Assessment of its Performance in Santa Maria Public Market, Poblacion, Santa Maria, Bulacan" and sought to answer the following questions:

1. How does demographic profile of the respondents be gauged in terms of:
    1.1. Age
    1.2. Sex
    1.3. Frequency of going to public market
    1.4. Length of residency
2. How is the public market affected by flooding assessed in terms of:
    2.1. Condition of drainage
    2.2. Topography and slope of area
    2.3. Lack of proper monitoring
    2.4. Solid waste management practices
    2.5. Capacity of drainage

3. How effective is the implementation of the public market design of drainage systems in terms of:
    3.1. Layout and functionality of drainage system
    3.2. Cost-effective materials used in construction
    3.3. Operation and maintenance
4. How can the improvement on the design of drainage system to minimize flooding in public market be of beneficial to the community of Santa Maria, Bulacan in terms of:
    4.1. Environmental Impact
    4.2. Safety and Resilience

Objective of the Study

The goal of this study is to assess the efficiency of the enhanced drainage system in Santa Maria Public Market, by evaluating its proper flood control, sanitation and functionality of the public market.

1. To gauge the demographic profile of the respondents in terms of:
    1.1. Age
    1.2. Sex
    1.3. Frequency of going to public market
    1.4. Length of Residency
2. To assess the public market affected by flooding in terms of:
    2.1. Condition of drainage

2.2. Topography and slope of area

2.3. Lack of proper monitoring

2.4. Capacity of drainage

3. To examine the effective implementation of the public market design of drainage systems in terms of:

3.1. Layout and functionality of drainage system

3.2. Cost-effective materials used in construction

3.3. Operation and maintenance

4. To evaluate the improvement on the design of drainage system to minimize flooding in public market be of beneficial to the community of Santa Maria, Bulacan in terms of:

4.1. Environmental Impact

4.2. Safety and Resilience

Research Hypotheses

Null Hypothesis (H_0): There is no significant effect in the design and performance assessment of an enhanced drainage system design to mitigate the flooding in the public market.

Alternative Hypothesis (H_a): There is a statistically significant effect in the design and performance assessment of an enhanced drainage system design to mitigate the flooding in the public market.

Significance of the Study

This study aims to reduce the economic problem in society and the performance assessment of an enhanced drainage system using High-Density Polyethylene (HDPE) Pipe in public market. To which will benefit the following:

For Residents of Santa Maria, Bulacan

This study will benefit the residents of Santa Maria to understand further the effects of having a proper and clean drainage system. The study helps reduce the health risk while being outdoor purchasing in the public market.

For Public Health

This study will be beneficial to the public health as it links to the effectiveness and performance of an enhanced drainage system that will promote good health and safety to the community. The implementation of an improved drainage system mitigates flooding, prevent diseases, and reduce insanitary conditions in the public market.

For Engineers

This research may help engineers to gain a better understanding of how HDPE pipe can be used to improve drainage systems in public markets. The study can support them in planning drainage designs that reduce flooding and manage rainwater more efficiently. With this information, engineers may select more suitable materials and develop systems that are safer, more durable, and beneficial for community and public use.

For Engineering Student

It will serve as a valuable reference for students to widen their knowledge about drainage system design and implementation. Leads to gain insights about real-world problems such as flooding, health risks, and sanitation. Helps enhancing students' learning about hydrology and hydraulics. Moreover, prepares them to improve themselves and acknowledge the future to become an engineer.

For Future Researcher

This study will assist future researchers to identify the important data in the study which will open opportunities to learn, grow and develop a better understanding of drainage system. To improve the existing knowledge about this key issue.

Scope and Limitations

This study discusses the condition, design and performance of an enhanced drainage system using HDPE pipe in Santa Maria Public Market, located in Poblacion, Santa Maria, Bulacan. The research focuses on identifying the problems of the existing drainage facilities, such as flooding, foul odor, and waste accumulation, which affect sanitation, public health, and the daily activities of vendors and customers. The respondents of the study include vendors, customers, and selected residents who regularly interact with the public market, as they are the ones directly affected by the condition of the drainage system. The study also aims to evaluate how the current drainage system functions during rainfall and provide recommendations that may help improve its performance and support the overall cleanliness and safety of the market.

The study's scope is limited to the drainage system within Santa Maria Public Market and does not include nearby residential or commercial drainage facilities. Due to unforeseen circumstances, this study only has limited data in the drainage system of the public market as the Municipality of Santa Maria, Bulacan is not allowed to share and release information regarding the drainage system in the public market including their other infrastructure projects. As a result, the researchers used alternative tool to gather important data specifically the measurements of the public market. Construction and implementation of new drainage systems are not part of the study. In addition, the study is limited to two semesters and data gathering will rely on surveys and observations, which may be influenced by the availability and responses of participants. Lastly, the findings of this study are applicable only to Santa Maria Public Market and may not represent the conditions of other public markets with different infrastructures and settings.

Definition of terms

In order for the readers to fully comprehend the terms used in this study, the subsequent terms are defined conceptually and operationally.

Cost-Effective. It refers to the methods, materials, and design that achieve efficiency. In this study, it refers to the optimization of the drainage system in Santa Maria Public Market, ensuring that improvements provide long-term performance and sustainability without incurring excessive expenses.

High-Density Polyethylene (HDPE) Pipe. A flexible pipe made from plastic polymer characterized by its impressive strength-to-density ratio, strong, durable and high resistance to corrosion. It is primarily used for conveying wastewater, stormwater, and sewage, featuring a smooth interior for optimal flow efficiency and long-term use in various residential and industrial drainage applications.

Hydraulics. Study of the behavior and movement of fluid, particularly water through pipes, drainage structures. In this study, it refers to the analysis and application of water flow behavior in drainage systems, serving as the basis for improving their design and efficiency.

Hydrology. Study of movement, distribution and quality of Earth's surface. In this study, it refers to the understanding of water processes, particularly flooding, sanitation, and surface runoff, to help improve students' knowledge and application of drainage system design and implementation.

Layout. Design plan of the drainage systems indicates and showing the placement of structures, pipes, and channels.

Sanitation. Conditions and practices to help prevent health risks and maintain cleanliness caused by the poor wastewater management.

Slope. The degree of inclination or steepness of the surface influencing the acceleration and direction of water flow.

Solid waste. Any discarded materials like garbage and non-liquid waste generated by human activity that may affect the drainage system if not properly disposed.

Topography. The description and mapping of the physical features of the area, including the slope, elevation, and landforms influencing the flow and design of the drainage system.

Wastewater. Refers to used water that comes from households, establishments and public areas that contains waste materials and needed to be treated.

CHAPTER 2

Review of Related Literature and Studies

This chapter presents the relevant literature and studies that researchers review for strengthening the study.

This also demonstrates a further understanding of the field and provides a current context for the study. Moreover, this study also includes the research made by the local and foreign researchers.

Foreign Literature

According to Nguyen et al. (2021), to determine the durability and performance of both the virgin and recycled high-density polyethylene (HDPE), it has been exposed to the ultraviolet (UV) radiation and showed only minimal changes and sustain their structure and strength. The study examined and impact extended UV exposure (3600 hours under accelerated laboratory conditions) affects the chemical, morphological, thermal, and mechanical properties of ridged HDPE pipes that is frequently used for storm water drainage. In addition, the carbon black must be minimum of between 2% to 4% antioxidants, and UV stabilizers that demonstrate crucial in minimizing UV degradation, protecting the pipes from fragility or cracking. The study found that both recycled and virgin HDPE pipes continued a stable

structural and mechanical integrity despite of minor surface oxidation and small decreases in crystallinity and hardness. Proving that they are durable and suitable which can be utilized for long-term in road drainage system. These conclusions are important for drainage engineering, as they verify that the recycled HDPE can perform similarly to virgin HDPE in drainage applications, offering a sustainable, cost-effective, and UV-resistant material option for use in road and storm water drainage systems, where exposure to sunlight and environmental conditions is inevitable.

Flooding is acknowledged as a leading persistent and damaging natural disasters and its effect aggravated in urban areas because of interruptions in drainage system including the encroachments, land reclamation, degenerating sewerage networks, and the reduction of environmental shields like mangroves according to Gaurkhede et al. (2021). Studies highlights that flood occurrence are intensified by both natural factors like extreme rainfall and anthropogenic pressures including unplanned urbanization and poor governance. As a result of lack of maintenance in drains, garbage dumping by irresponsible citizens, dilapidated and faltering drainage system, the water flow in the drainage system during rainfall is obstructed. The drainage system approaches have been found inadequate in discussing these matter, stimulate a recommendation for Sustainable Urban Drainage Systems (SuDS) that imitate natural hydrological processes to manage storm water, diminish runoff, and increase water quality. Urban areas prone to persistent inundation may alter their drainage systems into adaptable and multifunctional networks that not only reduce flood risks but also support long-term environmental sustainability in Mumbai, India.

As stated by Gao, Wang and Yang (2022), urban flood resilience has become a global research priority as a result of growing number of occurrence of extreme rainfall events connected to climate change. Urban floods are complicated events influenced by risk factors such as population density, infrastructure quality, and socioeconomic conditions, while effective management and adaptation strategies are vital to reduce risks. Existing studies features the role of frameworks that integrate flood risk assessment, governance approaches and the use of models such as GIS-based simulations and resilience indices in assessing urban planning and drainage systems are central to adaptability with creative solutions such as green infrastructure and sponge city concept is popularly used. Regardless of these developments, it designates the insufficiency of having a standardized frameworks and verified indicators, emphasizing the necessity for the context-specific applications that discourse both structural and non-structural elements of demonstrating resilience to urban flooding.

The failure of sewerage and drainage systems in Sub-Saharan African cities, particularly in Abidjan, Côte d'Ivoire, provides a serious environmental and management concern. This research emphasizes that poor solid waste disposal, unauthorized and faulty sewer connections, aging infrastructure, and natural phenomena such as erosion and landslides notably contribute to system breakdown, leading to blockages, leaks, and groundwater contamination. According to Ouattara et al. (2023), there is a thorough and practical link between the use of HDPE (High-Density Polyethylene) pipe in the drainage system and the effective implementation

of Wastewater Treatment for achieving proper sanitation. This study highlights that HDPE is a preferred material for the sewerage system in Abidjan due to its strong advantages particularly its resistance to corrosion, protection against chemical damage, and long-term durability. Choosing this material is essential because the pipe system acts as the main channel that collects household wastewater and safely transfers it to the designated pre-treatment and ultimate wastewater treatment plants. Despite Abidjan having one of the most extensive sewerage networks in West Africa, rapid urban growth and poor management practices have aggravated these failures, exposing communities to health and environmental risks. They conclude that lacking in stronger policy enforcement and systematic management, sewerage networks in escalating African cities will continue to deteriorate, weaken urban resilience and sustainable development. Therefore, the study emphasizes the strength and reliability of the HDPE pipe within the drainage system, highlighting its operational effectiveness and environmental objectives of the entire wastewater treatment and sanitation program.

Based on the study of Leandro (2020), the frequency and intensity of flooding in urban areas represent a significant aspect of the challenges faced by people in cities globally. This problem is worsened by climate change, inadequate drainage systems, and rapid urban expansion. Urban flooding made it tough for many cities around the world to be orderly safe and maintain its good condition. Aiming on the long-term use and assessing the solutions to ensure a resilience for flood management system. The weather events add up to the challenges in flooding and required to have a better strategy in making a sustainable development in drainage system. As findings reveal

a clear gap between public awareness of flooding risks and confidence in existing infrastructure, exposing shortcomings of traditional methods. By combining green infrastructure with conventional approaches, the study emphasizes viable strategies for strengthening urban resilience against flooding while calling for broader participation, long-term investigations, and adaptive solutions in various urban contexts.

Local Literature

According to Garcia et al. (2024), various studies explored the relative performance and cost-effective of High-Density Polyethylene (HDPE) pipes and Reinforced Concrete Pipes (RCP) in applications of drainage system. Usually, RCPs have been the typical choice for its durability, ability to withstand heavy loads, integrity and stresses in environment. Though, HDPE have positioned as a strong substitute as it offers advantages particularly in lighter weight, chemical resistance, flexibility, and ease in installation and due to its advancements in plastic technology. Using tools like force field analysis and FAST diagrams reveal that HDPE pipes are more cost-effective in the long term. In spite of HDPE's higher material cost and limited local availability studies show that it can lessen the operation and maintenance costs by 5.88% in comparison with RCP. Installation of HDPE causes less disruption, reducing construction-related delays and traffic congestion. The existing literature provide support for the utilization of HDPE pipes viable and effective as an alternative for small- to medium-scale drainage systems.

According to Malinay et al. (2023), across human history the drainage systems have been necessary for the advancement of civilization and public health. The study focused on the repeated problems such as flooding, health risks, and water quality issues that mainly root is the poor drainage facility together with the growing population. The government took action through application of regulations, statutes, rules, which highlighted as vital in ensuring an appropriate disposal of waste and mitigating drainage overflow. Sustainable Urban Drainage Systems (SuDS) integration, such as nature-based solutions like harvesting rain water, bioretention areas, and permeable pavements, is considered to be a useful strategy to enhance flood resilience and adjust to varying water cycle. It is also important to pick the ideal strategy for drainage system management in view of the available resources and best techniques meeting the resources of the nation.

As stated by Chua et al. (2023), the efficiency of drainage systems in the Philippines is greatly affected by rapid urban growth, insufficient waste management practices, and limited infrastructure, all of which lead to often flooding in densely populated regions. The literature shows the government interventions, including the policies on waste management and flood mitigation programs. It is critical but often inadequately enforced, leading to frequently overflow drainage and risks in health. Highlighting both policy enforcement and the adoption of innovative, eco-friendly drainage solutions, the study offers valuable understanding into coping with the continuous flooding challenges in urban communities.

Flooding is a common problem in the Philippines, especially in Cebu City and specifically in Barangay Basak in Lapu-Lapu City that did not exempt from the issue. As the problem turned into a major worry, it deeply impacts the whole community. According to Baguio et al. (2024), this research analyzed the drainage system in Barangay Basak and evaluated the current flood control methods in its sitios, at the same time also identifying the elements that aggravate flooding during extreme rainfall. Gather information through surveys, interviews, and the GIS mapping helps to better understand the situation and recommend solutions. The outcome revealed that 41.41% of the residents experience the flooding event in their area and 38.82% indicated that the inadequate disposal of garbage is the main reason of drainage overflow. Furthermore, the study found that flooding become worse due to the poor condition of the existing drainage and some sitios lack in drainage system. To address these matter, a properly constructed drainage system with a huge capacity and better design can be helpful for the community is recommended. Also, implementing a strict rule for disposal of waste can make more improvements.

This research used a geospatial method to detect suitable places for rainwater harvesting areas in Mandaue City, an urbanized area in Cebu, Philippines. According to the research by Bañados and Quijano (2022), employing GIS to gather data, information, and examine relationships and patterns aids in identifying an optimal site for constructing rainwater retention, which will serve as storage for rainwater, preventing it from directly entering the drainage system and thereby lowering the flood risk during rain. The analysis included surface runoff, elevation, soil type, land use,

and existing drainage system. It was found that about 54.8% of the area is suitable for water harvesting, but only 2.3% is ideal because it is in open land areas with clay loam soil and low elevation (0-25 meters). This is of great help to urban planners and LGUs because water can be redirected to these sites to reduce flooding, avoid traffic, and even use the collected water for the surrounding soil and plants.

Foreign Studies

According to Zhang et al. (2022), high-density polyethylene (HDPE) pipes are widely used in landfill drainage systems because of their durability and resistance to chemical degradation. The research examined how HDPE pipes deform when subjected to both external pressure and high temperature, conditions similar to those found in buried drainage systems. In model experiments using 110mm HDPE pipes buried in sand, it was observed that rising temperatures between 60°C and 80°C, combined with increased pressure, caused significant deformation and strain on the pipes. The pipe shape transformed from an ellipse to a more rectangular form as the temperature increased, demonstrating that both heat and pressure greatly influence its structural stability. The study stresses the importance of considering soil stiffness, load effects, and temperature fluctuations in the design of underground HDPE drainage systems to ensure long-term reliability and performance.

According to Shen et al. (2023), frequent urban flooding has been overwhelming traditional grey infrastructure, reducing the effectiveness of drainage systems during periods of heavy rainfall. To address this problem, the study proposed

a method of identifying critical nodes in drainage systems by combining hydraulic properties with sewer network topology. Fourteen layout concepts were developed by integrating green infrastructure (GI) features, such as rain barrels, into both underperforming and well-performing nodes. The findings indicated that targeted GI implementation can significantly reduce the risk of urban flooding and improve the coordination between GI and existing drainage systems.

As examined by Aprialdi et al. (2022), the drainage capacity of the Lebong Hitam River in South-Eastern Sumatra is affected by both tidal influence and blockages along its channels. Their study, which used five monitoring stations to record water levels, flow, and bathymetry, found that river cleaning greatly improved upstream conditions by increasing discharge and velocity more than five times while lowering water depth by over 40%. On the other hand, downstream areas were still mainly controlled by sea level. The findings suggest that river cleaning is an effective way to reduce flood risks in upstream areas of tropical lowland drainage systems, but it is less effective in downstream parts where tidal influence is stronger.

As reported by Zhang et al. (2023), urban surface flooding (USF) in Guangzhou during 2022 was closely linked to rainfall conditions and the efficiency of the drainage system. The study noted that although flooding risks were also present in non-flood seasons, more incidents occurred during the peak flood season. Data showed that flooding usually reached its peak within 50 minutes, which means immediate action is needed within 25 minutes to lessen the damage. The researchers also highlighted that most floods were of the surface runoff type, pointing to the importance

of improving flood simulation methods, maintaining rainwater inlets properly, and promoting proactive community measures through a classification-based approach to flood risk management.

As observed by Ma et al. (2024), the rising cases of urban flooding in China are mainly due to poor surface runoff management and limited local mitigation, problems that start from the planning stage of cities. The study emphasized that the absence of a major drainage system in urban stormwater management has worsened flooding impacts. To address this, the researchers proposed the development of Master Drainage Plans (MDPs) as an effective step toward creating proper stormwater systems and ensuring accurate local mitigation strategies. Lessons learned from this case study are not only useful for China but also applicable to other rapidly urbanizing nations facing similar flooding threats.

Local Studies

According to Luyun and Elazegui (2020), their study "Assessing the Resurgent Irrigation Development Program of the Philippines – Communal Irrigation Systems Component" examined the technical and operational performance of various communal irrigation systems (CIS) across Luzon, Visayas, and Mindanao. Findings revealed that many systems encountered issues such as insufficient water supply, canal deterioration, sediment buildup, and poor drainage, which frequently caused flooding during the rainy season. The research also recommended the utilization of high-density polyethylene (HDPE) pipes as an effective and economical material for subsurface

water conveyance, emphasizing their potential to improve irrigation and drainage infrastructure. The findings support the present study, as it emphasizes the role of HDPE pipes in developing a more durable and effective drainage system, particularly in areas like public markets that frequently encounter flooding issues.

As presented by Almendras et al. (2023), the study was conducted at Cebu Technological University–Pinamungajan Campus to develop and install a perforated PVC drainage system and to assess its acceptability and effectiveness. The system was evaluated in terms of its effectiveness, sustainability, awareness, safety, and health acceptability. Findings showed that the Technology Management of the Drainage System was highly acceptable and in line with the National Building Code of the Philippines and the Plumbing Code of the Philippines. The researchers also recommended the adoption and implementation of this drainage system management to ensure proper maintenance and to safeguard the users.

As indicated by Daang et al. (2023), the areas surrounding the Ilugin–Buli channel in Pasig City are prone to flooding since it serves as a tributary of the Pasig–Laguna River. The study generated flood scenarios for 2-, 5-, 20-, and 25-year return periods using both hydrologic and hydraulic models. HEC-HMS was used for hydrologic modeling with the SCS Curve Number for infiltration and the Clark Unit Hydrograph for the transform method, while the Muskingum Cunge method was used for routing. HEC-RAS was employed to develop both 1D and 2D hydraulic models of the channel. The results indicated flood depths ranging from 0.05 to 1 meter along the channel banks, while other areas recorded depths of less than 0.05 meter. The 1D

model showed upstream flooding caused by the limited capacity of the channel, whereas the 2D model provided a more detailed representation of flood depth, velocity, and surface elevation.

As described by Frias (2021), sustainable urban stormwater management practices, particularly Low Impact Development (LID), can help address common issues in developing countries like the Philippines, including water shortage, surface runoff, and declining water quality. The study was carried out at De La Salle University–Laguna Campus and tested 810 simulation scenarios using the Stormwater Management Model (SWMM). These scenarios involved the use of delineated sub catchments, different rainfall intensities (from the 60^{th} to the 95^{th} percentile), eight LID technologies (bioretention cell, infiltration trench, rain garden, green roof, permeable pavement, rain barrel, rooftop disconnection, and vegetative swale), along with a baseline conventional drainage system. The results showed that LID applications reduced runoff by 12% to 80% and increased infiltration by 0% to 55%, depending on the intervention type. Among the technologies, the infiltration trench performed best, with a required 9:1 or 1:1 green-gray ratio depending on the sub catchment condition. The study concluded that the optimum ratio is 11:5, since adding more green space beyond this point shows minimal improvement. This research highlights the adaptability of LID in the Philippine setting and offers practical guidelines for future studies on water management and flood mitigation.

As discussed by Castilla et al. (2024), flooding continues to pose a serious challenge to the residents of Barangay Danglag, Consolacion, Cebu, even with the

measures already implemented to address it. The study looked into the causes, effects, and adaptive responses of households located near the Danglag–Laray Creek. Survey results from 29 households showed that most families lived on residential lots smaller than 100 square meters and had experienced recurring floods in the past decade, with some incidents reaching up to the second floor of their homes. Its consequences included damage to properties and crops, added stress to residents, and the loss of time needed for clean-up activities. Records also showed that floods occurred one to three times within a ten-year span, resulting in harm to lawns, trees, shrubs, fences, and other household structures. To lessen these impacts, residents implemented measures such as planting Mahogany and Madre de Cacao trees and applying permeable paving. These efforts emphasize the importance of strengthening community-based solutions to improve resilience against future flooding.

Synthesis of Related Literature and Studies

The synthesis of various research findings highlights the significant advancements in the Enhanced Drainage System, particularly in addressing urban flooding, sanitation, and environmental sustainability. Both foreign and local studies point out that the common cause of drainage failure is poor waste management, rapid urbanization, and outdated drainage systems. At the same time, new approaches such as Sustainable Urban Drainage System (SUDS), Low Impact Development (LID) and rainwater catchment are recognized as promising solutions for strengthening resilience in flood-prone areas.

Across the foreign literature, Nguyen et al. (2021) and Zhang et al. (2022) analyzed the durability and structural performance of High-Density Polyethylene (HDPE) pipes, emphasizing their strong resistance to UV radiation, pressure, and temperature changes, making them a reliable material for stormwater and landfill drainage systems due to its strength and adapting under varying environmental condition. These findings align with the local literature of Garcia et al. (2024) and Luyun and Elazegui (2020), which recognized the cost-efficiency and long-term reliability of HDPE as an alternative to traditional Reinforced Concrete Pipes (RCP), especially in enhancing irrigation and drainage infrastructure. Together, these studies verify that HDPE is a sustainable and durable option for improving local drainage infrastructure.

The reviewed studies share similarities stressing the importance of a sustainable drainage system. For instance, Gaurkhede et al. (2021), Leandro (2020), and Gao et al. (2022) highlighted the need for Sustainable Urban Drainage System (SUDS) and green infrastructures in urban flood management to regulate the stormwater, while Frias (2021) shows how the Low Impact Development (LID) technologies can significantly reduce runoff and minimize the flooding in the Philippines. Likewise, Bañados and Quijano (2022) address the values of rainwater harvesting and GIS mapping in identifying effective flood mitigation sites. All of these studies agree that integrating sustainable methods into drainage management is essential to manage flooding effectively.

In examining the differences across the literature and studies, Gaurkhede, Adane, and Khonde (2021), Gao, Wang, and Yang (2022), Ouattara et al. (2023), and Leandro (2020) analyzes the urban flooding, dwelling on many factors like poor governance, unplanned urbanization, outdated infrastructure and climate change. Their proposed solutions include Sustainable Urban Drainage Systems (SuDS), sponge city concepts, and GIS-based frameworks which apply across urban areas. Similarly, Shen et al. (2023), Aprialdi et al. (2022), Zhang et al. (2023), and Ma et al. (2024) in the foreign studies depict the utilization of hydrologic-hydraulic models and nature-based solutions for broader flood mitigation. Whereas in the local literature by Malinay et al. (2023), Chua et al. (2023), Baguio et al. (2024), and Bañados and Quijano (2022) prioritize on the persistent flooding caused by poor waste disposal, weak enforcement, and rapid urbanization that mainly proposing measures such as rainwater catchment, geospatial mapping, and green infrastructure at the same time. In the same way, local studies are conducted by Almendras et al. (2023), Daang et al. (2023), Frias (2021), and Castilla et al. (2024) assessed the functionality of the drainage system by utilizing the modeling tools and pilot projects applied in communities, campuses, and residential areas. Examine comparatively with these works, the present study in the public market in Santa Maria, Bulacan departs from the idea of larger aspect of urban planning, regional scales, employing simulation models such as GIS, SWMM, hydrologic-hydraulic recommend long-term strategies like SuDS, LID, or Master Drainage Plans (Shkaruba et al., 2020; Frias, 2021). In the present study, it concentrated mainly on a micro-level or on a small scale which is in

the public market of Santa Maria, Bulacan where small aspects such as garbage accumulation and drainage layout are a big part of flooding. The research gap reveals that many studies about drainage systems have only a few who address localized drainage issues in community hubs such as public markets, where operational inefficiencies directly hinder flood resilience. Adding that wastewater treatment is rarely mentioned in the studies provided, shows that it is not given much attention as core and essential part of drainage system.

In conclusion, the reviewed literature and studies reveal that urban flooding is commonly linked to inadequate drainage systems, poor maintenance, and unregulated waste disposal, with most works focusing on broad city-wide or regional strategies using models and frameworks. Unlike studies assessing entire cities, watersheds, and residential areas, this study focuses on the public market where flooding directly affects daily commerce, sanitation and community safety. While past studies emphasize broader community-based planning or household resilience, this study narrows its scope to examine how the drainage effectiveness impacts the vendors and consumers in the public market, where overlooked everyday problems significantly affect flood resilience. By examining the micro-level effectiveness of HDPE pipe drainage systems and their role in mitigating localized flooding, this study addresses a key research gap and contributes practical insights toward improving community resilience and sustainable flood management in small-scale urban environments.

CHAPTER 3

Methodology

This chapter concentrates on the discourse of the research methods and procedure in order for the researchers to answer the specific problem in this study. It also includes the population, gathering data, research instruments, as well as the statistical treatment of data applied for the precise analysis of data that were explained in this chapter.

Research Design

This study used an experimental quantitative method of research. The researchers chose this method because it is more appropriate to establish a verifiable cause-and-effect relationship between variables and produce accurate, measurable result vital for determining the effectiveness of the implemented drainage system at Santa Maria Public Market compared to the existing one. This method utilizes a Quasi-Experimental Design where the independent variable is the installation of the Enhanced Drainage System Design using HDPE Pipe, and the definite performance metrics, such as Flow Rate (Q), Clearance Time and Flood Depth. In addition, it employs a dual analytical approach which Design Calculations and Hydraulic Modeling utilize Rational Method to calculate the required peak design flow rate and

wastewater calculation for the new drainage system at the same time Paired Samples T-test is utilized in statistical treatment to examine the collected data by comparing the standard performance data, pre-test with the post-test that will equitably determine the observed improvement in drainage performance is significant. The expected outcome will determine the effectiveness of an implemented drainage system in the public market from the existing.

Design Calculations and Hydraulic Modeling

1. Stormwater Peak Flow Calculation

The Flow Rate (Q) of a drainage system is described as a volume of water passing at a specific point per unit time usually measured in cubic meters per second (m^3/s). Flow Rate is a primary variable used in hydraulic design and evaluation in storm drainage networks. It was calculated using methods typically the standard engineering formula like Rational Method ($Q = CiA$) in order to determine the peak discharge of the maximum expected flow rate during a defined design storm event. The peak value ensures that the proposed or existing system accuracy of determining peak adequacy capacity to convey stormwater effectively, preventing localized flooding and protecting public infrastructure and health. Additionally, the Rainfall Intensity (i) it is a critical parameter in computing peak discharge using rational method representing the rate of rainfall in terms of depth per unit time (mm/hr). The value of Rainfall Intensity will be obtained by the use of official and reliable historical data obtained from PAGASA (Philippine, Atmospheric, Geophysical and Astronomical Services Administration). This intensity must be selected based on their

Design Return Period (T) and calculated Time Concentration (t_c) ensures that the intensity used is appropriate.

2. Wastewater Flow Calculation

It determines the necessary capacity of the separate sewer system by proving Population Equivalent (PE) which substitutes non-residential activity of the market into a functional measure of flow. This PE is utilized with consumption standards to determine the Average Daily Flow (Q_{avg}), which will only be achieve by evaluating the number of marker users and multiplying by a standard per capita flow. It is incorporated into the study because it is vital by demonstrating the reliability and viability of enhanced drainage system using HDPE pipe. The primary goal of the enhancement is to separate the flows, since the existing systems is combined drainage system. This requires calculating the required measurements of the enhanced drainage system to guarantee that it can effectively divert the continuous flow of sewage and grey water that present overloads to the stormwater lines. Peak Sanitary Flow is computed by multiplying Average Daily Flow by the Peak Factor (PF) which accounts for maximum discharge during peak market hours. This calculated flow later be utilized in the Manning Equation to establish the fundamental minimum pipe slope and diameter for a dedicated sanitary line. By demonstrating the technical viability of diverting the Peak Sanitary Flow, the research certify that the enhanced drainage system pipe will only convey stormwater consequently ensure a maximum efficiency and executing the core objective of flow separation.

Sample and Population

The simple random sampling technique is utilized in this research, wherein the researchers selected the respondents randomly but everyone has a chance to be picked. The study will include at least 100 participants, which includes the residents, vendors and consumers from the location. These participants will thorough the survey that the researcher will conduct.

Research Instrument

There are few instrument that the researchers utilized to gather data or information for the design and performance of the proposed drainage system using HDPE pipe. Data is necessary to answer the problems in this study.

1. Survey

The researchers prepare a set of questionnaires to be distributed to the respondents. The questionnaires for the survey will consist of the questions that are related to the study. The functionality and effectiveness of the study will be resolved through the questionnaire and the gathered data from the questionnaires will give more information and support to the study. This research necessitates the application of frequency, percentage, and weighted mean.

2. AutoCAD

AutoCAD is a preferred tool for designing a Drainage System using HDPE pipe material because of its precision and efficiency. It is utilized to create a detailed and accurate technical drawings of drainage network with the exact 2D layout of

HDPE pipes, fittings and structures. Since HDPE pipe has a specific flexibility and installation requirements, AutoCAD helps to visualize and compute the right lengths, slopes and junctions to ensure that the design follows the engineering standards and site condition.

3. STAAD Pro

The researchers utilized STAAD Pro to help accurately model the viscoelastic property of plastic to check if the deflection will not exceed to its allowable limit. Since HDPE is a flexible pipe its structural integrity is dependent on the support of surrounding soil. It serves as a useful tool for analyzing and designing structures by stimulating how they behave under various loads, ensuring efficiently and reliably. STAAD Pro main function to this study is to verify the whole system including pipe and soil for its stability and the stress levels of the plastic pipe is safe for its long-term use.

4. SketchUp

It will be used specifically for three dimensional (3D) visualization and modeling of the enhanced drainage system design. SketchUp helps to create a photo-realistic model of the HDPE pipe. Moreover, the model will be utilized for systematic quantity takeoff, directly pulling out the exact lengths of HDPE pipes and the number of needed fittings. Vital for the subsequent economic evaluation of the proposed drainage system.

Data Gathering

The factors that contributed to the data gathering of the researchers for this study were the survey, technical drawings, structural analysis and visualization. The researchers conducted a survey for the study to determine how much people were affected in the existing drainage system in the public market and how the people were in favor of designing a drainage system that can accommodate the stormwater effectively. The researchers will make an online survey questionnaire and it will be designated only for those who meets the researchers required standard of respondents. The process of collection of the answered survey questionnaire will definitely last between 5 to 7 days. When the survey ended, the data gathered and collected information were analyzed. Technical drawings provide data about physical reality of site including the precise measurements, dimensions and materials specifications. Structural Analysis serves as the documentation that verifies the adherence of design to safety standards. Provides data on structure load capacity, feasibility and safety established by the required industry codes. In visualization, it allows to create a detailed 3D model of the HDPE pipe network and its elements. This 3D presentation is distinctly shows the pipe layout, depths, slopes and the assimilation of the enhanced drainage system within the Santa Maria Public Market. Furthermore, data collection will also focus on measuring water stage, flow rate, rainfall intensity, flood depth, clearance time and wastewater calculations at selected locations throughout the market. To measure the flood depth, the highest water level reached during rainfall will be recorded, while in clearance time, it will measure on how long it takes for water to drop below a safe level after rainfall stops. The Rational Method will be calculated

to determine the peak discharge of the maximum expected flow rate, rainfall will be tracked using a rainfall history from authoritative source of weather information (PAGASA).

Statistical Treatment

The researchers utilized a statistical tool to the data in this study. It obtained an accurate guide to proper analysis and drawing appropriate conclusions from the data acquired. The tools utilized for statistical analysis in this research are as follows.

1. Paired Samples T-test

   This statistical test is utilized to compare the significant difference between the means of two related groups or pairs. Based on the assumption that the contrast between the pairs are commonly distributed.

$$t = \frac{\bar{d}}{\frac{s_d}{\sqrt{n}}}$$

   where:

   t = calculated t-statistic

   $\bar{d}$ = mean of the different scores

   s_d = standard deviation of different scores

   n = numbers of pairs of observations

2. Frequency and Percentage Method

   The percent and frequency distribution are the ones that is used to classify the respondents according to their personal background information such as name (optional), age, and sex. The percentage of those items will be computed by

dividing it with the same total numbers of respondents who will participate in the survey using the formula.

$$P = f/n \times 100$$

Where:

p = percentage

f = frequency

n = total number of responses

3. Weighted Mean

To establish when certain data points in a collection are regarded as more significant than the rest and the formula;

$$W = \sum fx/N$$

Where:

W = Weighted Mean

F = Frequency

x = scale or Criteria

N = Total Number of Respondents

Survey Questionnaires

Title: Design and Performance Assessment of an Enhanced Drainage System using High-Density Polyethylene (HDPE) Pipe in Santa Maria Public Market, Poblacion, Santa Maria, Bulacan

Please answer the following items honestly. This questionnaire aims to gather data about the drainage system in the Santa Maria Public Market. Your responses will be used solely for academic purposes and will be treated with strict confidentiality.

Part I. Demographic Profile of the Respondents

1. Name (Optional): _____
2. Age:
3. Sex:

   ☐ Male ☐ Female

4. Frequency of going to the public market:

   ☐ Daily ☐ 3–4 times a week ☐ Once a week ☐ Occasionally

5. Length of residency in Santa Maria, Bulacan:

   ☐ Less than 1 year ☐ 1–5 years

   ☐ 6–10 years ☐ More than 10 years

Part II. Please indicate your level of agreement with each of the following statements by checking one box per row.

Scale:

5 = Strongly Agree, **4** = Agree, **3** = Neutral, **2** = Disagree, **1** = Strongly Disagree

2.1. Condition of Drainage System	5	4	3	2	1
2.1.1 The current condition of the drainage system is well maintained by the management.					
2.1.2 Drainage canals are regularly maintained to avoid blockages and flooding.					
2.1.3 The drainage system functions effectively even during intense rainfall.					

2.2. Topography and Slope of Area	5	4	3	2	1
2.2.1 The market area is higher than other places, so water doesn't stay long when it rains.					
2.2.2 The slope or level of the market helps rainwater flow out easily.					
2.2.3 Some parts of the market are lower, causing water to collect or flood in those spots.					

2.3. Lack of Proper Monitoring	5	4	3	2	1
2.3.1 The drainage system does receive proper monitoring and cleaning regularly.					
2.3.2 There is a set schedule for checking the drainage condition.					
2.3.3 Flooding happens because the drainage is not properly or regularly monitored.					

2.4. Solid Waste Management Practices	5	4	3	2	1
2.4.1 There are management practices about the proper disposal and sanitation of solid waste especially by vendors in the Public Market.					
2.4.2 Vendors follow proper ways of separating and throwing their garbage to avoid clogging the drainage.					
2.4.3 Improper waste disposal by both vendors and customers contributes to flooding issues.					

2.5. Capacity of Drainage	5	4	3	2	1
2.5.1 The Drainage System can handle large volume of rainwater during heavy rains.					
2.5.2 The drainage seems capable of handling wastewater even during peak hours.					
2.5.3 When it rains for a long time, the drainage overflows easily.					

3.1. Layout and Functionality of Drainage System	5	4	3	2	1
3.1.1 The drainage works well and lets water pass through easily during heavy rain.					
3.1.2 The slope or level of the drainage helps the water drain faster.					
3.1.3 The drainage system does not give off unpleasant odor under normal conditions.					

3.2. Cost-Effective Materials Used in Construction	5	4	3	2	1
3.2.1 The drainage is made of strong materials that can last a long time.					
3.2.2 The materials used do not easily get damaged, even during heavy rain.					
3.2.3 The materials used are suitable for the drainage system and worth the cost.					

3.3. Operation and Maintenance	5	4	3	2	1
3.3.1 The Management regularly maintained the cleanliness of Drainage canals in the public market to ensure effective water flow.					
3.3.2 The drainage system is inspected to identify blockages or damages.					
3.3.3 The local government provides enough help or budget to clean and maintain the drainage.					

4.1. Environmental Impact	5	4	3	2	1
4.1.1 Enhancing the drainage system can minimize standing water and unpleasant odors in the market area.					
4.1.2 Effective drainage improvements promote cleanliness and sanitation around the market.					
4.1.3 Better drainage will help keep the market area free from pests that carry diseases (like mosquitoes and rats).					

4.2. Safety and Resilience	5	4	3	2	1
4.2.1 A well-constructed drainage system can prevent accidents and property damage during flood events.					
4.2.2 The improved drainage system can handle heavy rain without causing floods.					
4.2.3 Putting covers and warning signs near drainage canals helps prevent accidents. Installing adequate covers and signage near drainage canals enhances public safety.					

CERTIFICATE OF VALIDATION

This is to certify that the research instrument used in the study entitled, "**DESIGN OF AN ENHANCED DRAINAGE SYSTEM USING HIGH-DENSITY POLYETHYLENE (HDPE) PIPE AND ASSESSMENT OF ITS PERFORMANCE IN SANTA MARIA PUBLIC MARKET, POBLACION, SANTA MARIA, BULACAN**", conducted by Group B10 namely, Jessica Mae L. Ignacio, Kristine May B. Macalalag, and Mark Daniel I. Sinon from Civil Engineering Department, La Concepcion College, has been validated by the undersigned expert.

After thorough evaluation, the validator confirms that the instrument meets the required standards for clarity, relevance, accuracy, consistency, appropriateness to the study objectives. The validator affirms that the instrument is suitable for data gathering and may be used for academic research purposes.

Issued this 4th day of November, 2025.

Validators:

ENGR. JORE GIL D. GALEZA	**ENGR. ROMIEL C. BASCO**	**ENGR. ELOISA P. CADAG**
Validator	**Validator**	**Validator**